

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-257 849

Preliminary Emissions Assessment of Conventional Stationary Combustion Systems. Volume III

GCA Corp, Bedford, Mass GCA Technology Div

Prepared for

Industrial Environmental Research Lab, Research Triangle Park, N C

Aug 76

274034

PB 257 849

EPA-600/2-76-046c
August 1976

Environmental Protection Technology Series



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SPRINGFIELD, VA. 22161

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EPA-600/2-76-046c

August 1976

**PRELIMINARY EMISSIONS ASSESSMENT
OF CONVENTIONAL
STATIONARY COMBUSTION SYSTEMS**

Volume III. Update (12/75-6/76)

by

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**Contract No. 68-02-1316, Task 16
ROAP No. AAU-002
Program Element No. EHB525**

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Prepared for

**U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, DC 20460**

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TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)			
1. REPORT NO. EPA-600/2-76-046c		3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE PRELIMINARY EMISSIONS ASSESSMENT OF CONVENTIONAL STATIONARY COMBUSTION SYSTEMS; Volume III. Update (12/75-6/76)		5. REPORT DATE August 1976	
7. AUTHOR(S) Norman Surprenant		6. PERFORMING ORGANIZATION CODE	
9. PERFORMING ORGANIZATION NAME AND ADDRESS GCA/Technology Division GCA Corporation Bedford, Massachusetts 01730		8. PERFORMING ORGANIZATION REPORT NO. GCA-TR-76-21-G	
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO. EH525; ROAP AAU-002	
		11. CONTRACT/GRANT NO. 68-02-1316, Task 16	
		13. TYPE OF REPORT AND PERIOD COVERED Update; 12/75-6/76	
		14. SPONSORING AGENCY CODE EPA-ORD	
15. SUPPLEMENTARY NOTES Project officer for this report is R. A. Venezia, 919/549-8411 Ext 2547, Mail Drop 62.			
16. ABSTRACT The report updates Volume II of this series (EPA-600/2-76-046b). It identifies and discusses major recent ongoing and proposed programs in the area of pollutant emissions from combustion sources. The information presented covers the period from December 1975 to June 1976 and was obtained through a review of the literature and contact with governmental and industrial representatives.			
17. KEY WORDS AND DOCUMENT ANALYSIS			
a. DESCRIPTORS		b. IDENTIFIERS, OPEN ENDED TERMS	c. COSATI Field Group
Pollution		Pollution Control	13B
Combustion		Stationary Sources	21B 10A
Utilities		Emissions Assessment	13A
Industries			05C 21G
Industrial Wastes			
Residential Buildings			
Steam Electric			
Power Generation			
Space Heating			
Stationary Engines			
18. DISTRIBUTION STATEMENT Unlimited		19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 51
		20. SECURITY CLASS (This page) Unclassified	22. PRICE 450

SECTION I

INTRODUCTION

The study of conventional stationary combustion sources and their emissions is an area of continued and growing interest to the Environmental Protection Agency. Four principal categories of conventional stationary combustion systems have been considered in this program:

- Utilities - electric generation
- Industrial - steam generation, space heating, and stationary engines (direct heating and chemical conversion were excluded)
- Commercial/Institutional - space heating and stationary engines
- Residential - space heating

As noted in the Final Report¹ issued under EPA Contract No. 68-02-1316, Task Order No. 11, entitled, "Preliminary Emissions Assessment of Conventional Stationary Combustion Systems," these combustion sources account for an estimated 20 percent of particulate, 71 percent of SO_2 , 44 percent of NO_x , 1 percent of CO, and 0.7 percent of HC emissions from man made sources in the United States.¹ The importance of combustion systems as a major source of particulate, SO_2 and NO_x emissions is apparent. Further interest stems from the fact that the emissions of trace elements and particularly trace hazardous compounds such as polycyclic organic matter (POM) have not been well characterized. Many of these potentially hazardous pollutants tend to concentrate on the surface of respirable, fine particulate matter and their impact on the environment and human health may be significant.

PROGRAM OBJECTIVE

The objective of this program is to update the preliminary emissions assessment report issued under EPA Contract No. 68-02-1316, Task Order No. 11. Literature sources, EPA reports and governmental and industrial contacts were used to identify new activities or information related to emissions from stationary combustion sources. No attempt has been made to utilize new emissions data to arrive at new estimates of emissions. Instead, this report discusses in detail some representative recently completed and ongoing projects which are pertinent to an emission assessment of conventional stationary combustion sources. A listing of recently awarded and proposed contracts is also provided. The presentation is similar to that presented in Section VII of the Final Report of the previous emissions assessment program and discussions are provided for the following areas of activity:

- Combustion
- Emissions - general
- Flue gas emissions
- Flue gas emissions - NO_x
- Water emissions and solid waste
- Fuels
- Control measures
- Solid waste utilization

Many of the new activities discussed are concerned with several of the areas listed. These programs are listed in the general category or in the area of most significant interest.

The most pertinent emissions assessment activity planned by EPA is one that will be issued under RFP DU-76-A106. Contractor(s) chosen for this program are now scheduled to commence work in the fall of 1976 on the assessment of emissions from 54 of the 56 combustion source categories examined under the previous contract. This 3 year field measurements and analysis program will utilize phased sampling and analytical techniques

to characterize combustion source categories and their air, water and solid waste emission streams. Monsanto Research Corporation, under EPA Contract, is already conducting similar assessments of the remaining two combustion source categories, pulverized dry bottom utility and industrial combustion sources. This work will be completed in 1977.

DATA SOURCES

Many governmental and institutional agencies are important sources of information concerning conventional stationary combustion sources and their emissions. These information sources were identified and utilized in the previous preliminary emissions assessment document. Since the publication of the above document, however, there have been some changes and additions to the available data information base which are of potential significance.

The Federal Power Commission (FPC) is the principal source of public information for the Electric Power Industry. FPC Form 67 contains information, provided by the electric power industry for all major power generators, with regard to plant size, fuel consumption, certain emissions and control measures. A change in the Form 67 reporting requirements is planned to take effect in 1976 which would require electric utilities to provide additional information on their emission control plans and costs for current and future fossil-fuel burning, steam-powered generating plants.² The new Part IV of FPC Form 67 is being reviewed by the general accounting office (GAO) and decision on the new reporting forms is expected in late spring of 1976. When cleared by GAO, Part IV of Form 67 would have to be submitted for 1976 and every year thereafter.

The new FPC reporting form is divided into six schedules to require detailed information on plans and costs for meeting air-pollution standards. The form also would require utilities with fossil-fuel boilers to provide data on design fuel consumption, the primary fuel to be fired, and the type of firing.

It would also require a plant to tell how stack-gas equipment will remove particulate matter and sulfur oxides. The percentage of design collection and efficiency and the total collecting surface area would have to be reported to show the amount of particulate matter the equipment can remove. Sulfur dioxide control measures would be identified and design and actual desulfurization efficiency detailed.

Another principal source of information regarding emissions to water utilized in the previous preliminary emission assessment program was the National Pollutant Discharge Elimination System (NPDES). Unfortunately this data is fragmented and only partially computerized and, therefore, difficult to use effectively in estimating emissions. A new data system, the Permit Compliance System (PCS) began operation in 1975 and is now used by 5 of the 10 EPA regional offices. This system and its future modification and enhancements and future computer systems planned for reporting data in the NPDES will prove useful in future activities concerned with wastewater discharges.

The four basic reports available from the system are:

- Forecast of Compliance Schedule Reports due,
- Forecast of Discharge Monitoring Reports due,
- "Quick Look" report with one line of information displayed for each facility on the file, and
- Facility report which lists all the information contained on the data file about the specific facilities selected in the retrieval.

Data are extracted from NPDES permits for entry into the system files. Generally, information is transcribed onto code sheets rather than punched directly from the permit documents. Users generate reports at their discretion. DMR and Compliance Schedule Forecast Reports are generated at least once each month, but can cover any period. Quick Look and Facility Reports are produced on request.

Regions are responsible for extracting data from applications and permits, and for coding, keypunching, data submission, review of pre-edit error listings, data corrections, review of update edit listings, and overall maintenance of the data base for their Region. EPA Headquarters has responsibility to develop and maintain all edit, update, and retrieval programs and procedures. Many of these responsibilities are handled by a private contractor. The system is maintained by EPA Headquarters Office of Enforcement under the Direction of the Deputy Assistant Administrator for Water Enforcement.

There is a continual and increasing need for the collection, validation, storage and retrieval of environmental data. Much of the data that has been collected is in scattered federal, state and industrial files. In theory some of this data goes into systems such as: EPA's National Emissions Data System (NEDS) and Source Test Data System (SOTDAT) for Air Emissions; EPA's (STORET) for water quality data; the National Water Data Exchange (NAWDEX) implemented through the U.S. Geological Survey's Office of Water Data Coordination; the Environmental Catalog of Industrial Processes (ECIP) which compiles process data, waste stream data, and industry information; the Strategic Environmental Assessment System (SEAS) dealing with waste stream rates and pollutants and industry information; and the Matrix of Environmental Residuals for Energy Systems (MERES) maintained by the Brookhaven National Laboratory for air, water, and solid waste pollution, health effects and system process data. Unfortunately most of the data that has been collected does not reach these systems and there is a critical need to assemble, validate and summarize these data to avoid costly and unnecessary duplication of effort. An organized effort should be made to do so and, if necessary, to develop a new data storage and retrieval system adequate for the development of a total environmental assessment of pollutants and industries. This program, which is concerned with the identification of recent, ongoing and planned programs, will be useful in subsequently achieving this overall data management objective.

SECTION II

COMBUSTION

This section covers the activities now underway or recently completed concerned with Fundamental Combustion Research (FCR) and process modification to reduce or modify combustion generated pollutants. The Combustion Research Branch (CRB) of EPA's Industrial Environmental Research Laboratory, Research Triangle Park (IERL/RTP) has been most active in these areas. However, other government agencies, such as NSF-RANN, the Energy Research and Development Agency (ERDA), the National Bureau of Standards (NBS), and the Air Force's Aero Propulsion Laboratory and Office of Scientific Research are also active. Fundamental combustion and process research activities are similarly carried out by equipment manufacturers and by industrial groups such as the Electric Power Research Institute, the American Gas Association, and the American Petroleum Institute.

A new publication, NO_x Control Reviews,³ issued first in March 1976 by the IERL/RTP, although specifically concerned with NO_x emissions, is a good source of information concerning combustion research and process modification. The first issue provided an overview of past development programs of the EPA and the private sector and summarized current control developments. Subsequent issues, to be published approximately bimonthly, will be devoted solely to current developments.

Another recent source of information is the published proceedings of the CRB-sponsored symposium on stationary source combustion held in Atlanta on September 24-26, 1975 to disseminate results of EPA in-house and contract

programs for development of controls for combustion generated air pollution. Sessions were held in the key program areas of the CRB: fundamental research, fuels R&D, process R&D and field testing and surveys.

The remainder of this section will discuss some representative EPA programs aimed at the modification of boilers to reduce emissions. While these programs are primarily concerned with NO_x control, emissions of other pollutants including SO_2 , CO, unburned hydrocarbons, trace organics particulates and trace elements are also of concern.

- Fundamental Combustion Research Applied to Pollution Control (EPA RFP DU-76-A157)

This recent RFP (Proposal due date June 7, 1976) was issued by the IERL/RFP Combustion Research Branch. It is concerned with the development and synthesis of an overall plan for the conduct of a fundamental combustion research (FCR) program. The plan will be based on current FCR activities, projected results from ongoing studies, and the fundamental data gaps identified in CRB's fuels R&D and process R&D programs. The program is concerned with control of all combustion generated pollutants, but primarily with those pollutants which may be controllable through combustion modification. Emphasis will be placed on NO_x , CO, SO_x and UHC with lesser emphasis on POM, sulfates, nitrates, etc. This is a large program (i.e., 70,000 technical labor hours) which is concerned with the full spectrum of conventional stationary combustion sources (and advanced combustion systems). The contractor selected for this program will be required to survey the existing data base and on going EPA and other governmental agency programs concerned with combustion research and should be able to provide a broad overview of existing activity in the fundamental combustion research area.

- Advance Combustion Systems for Stationary Gas Turbine Systems (United Technologies Corporation, West Palm Beach, Florida, EPA Contract No. 68-02-1316, Project Officer, W.S. Lanier, IERL/RTP)

This program, to develop advanced, low emission, gas turbine combustor designs will place primary emphasis on NO_x control by dry techniques while maintaining or reducing CO and HC levels. Design goals are 50 ppm NO_x at 15 percent O_2 for gas and light distillate oil fuels and 100 ppm NO_x for oils containing up to 0.5 percent chemically bound nitrogen. The

study will be performed in four phases (1) survey of potential design approaches; (2) bench scale testing of 12 candidate NO_x control techniques; (3) full scale design of two combustors selected from phase 2; and (4) verification testing of the full scale combustors.

- Pilot Scale Evaluation of Advanced Combustion Control Techniques for Fossil and Waste Fuels (Aerotherm Division of Acurex Corp., EPA Contract No. 68-02-1885, Project Officer, David G. LaChapell, IERL/RTP)

This 28-month pilot-scale test program uses a 3×10^6 Btu/hr capacity furnace that can be operated in either wall-fired or tangentially, corner-fired modes. Emphasis will be on two-stage combustion using coal, oil, gas, mixed fuels, waste fuels and several alternative fuels such as shale oil, low Btu gas and coal/oil slurries. Other control measures such as burner modifications, flue gas recirculation, and the modification of firebox and heat transfer surfaces will be studied. The time/temperature trajectory of the combustion gases in the test furnace is representative of industrial and utility boilers allowing translation to full scale equipment.

The following planned or recently awarded contracts, as noted in the Commerce Business Daily, (CBD), appear to apply to a study of conventional stationary source combustion.

- Design Optimization, Construction and Field Verification of Integrated Residential Furnace (EPA RFP DU-76-A173, CBD 5/17/76)

EPA contemplates negotiating with Rocketdyne Division, Rockwell International Corporation of Canoga Park, Ca. This procurement is a direct follow-on of EPA Contract No. 68-02-1819. R&D under EPA Contract No. 68-02-1819 has resulted in an experimental prototype integrated residential furnace fired with distillate oil. The next step is to optimize the prototype and heat exchanger design modification. This procurement will lead to such optimization followed by construction of a minimum of six integrated units which will be verified in field application.

- Evaluation of Liquid Cooled Gas Turbines (NASA RFP 3-741375Q, CBD 5/25/76)

A feasibility study will be performed to evaluate and compare various cooling concepts for several gas turbine applications including: electric power generation, autos, buses, trucks and marine.

- Study of the Performance of a Thermal Aerosol Oil Burner (EPA RFP LJ76-A214, CBD 6/7/76)

Negotiations are planned with Honeywell, Inc. Bloomington, Minn., to study air pollution reduction and efficiency for combustion of distillate oil.

- Air Pollution Emissions Control Development for Stationary Internal Combustion Engines (EPA RFP DU-76-A180, CBD 4/15/76)

EPA is seeking a contractor to conduct a program to develop advanced designs for large stationary reciprocating internal combustion engines. This program is designed so that it may be implemented by organizations under the direction and management of one contractor. The research effort will emphasize low NO_x emissions, improvement or maintenance of current low carbonaceous pollutant emissions from these engines and high thermal efficiency in the development of a new generation of piston engines. The Contractor will develop the design, construction and testing of new engines based on low emission concepts. The study will also investigate retrofit technology to existing engines.

- Technical Support and Assistance for the Development of Standards for Stationary IC Engines (Aerotherm Division of Acurex Corp. EPA RFP DU-76-C297, CBD 6/2/76)
- Investigation of NO_x, Nitrate and Sulfate Production in Laboratory Flues. (EPA RFP DU-76-A121, CBD 3/9/76)

Study of Nitrate, Sulfate and Precursors in Flue Zone.

SECTION III

EMISSIONS - GENERAL

Over the past few years there has been a strong interest in a more comprehensive determination of pollutants emitted from combustion sources and their waste streams (air, water and solid). This interest has been spurred by the potential health hazard and detrimental environmental impact of not only the criteria pollutants but of certain trace elements and hazardous compounds such as polycyclic organic matter (POM). The thrust of many ongoing programs is to identify and semiquantify any substances that may be of concern or serve as the precursors of such substances. Those pollutants identified which are deemed environmentally harmful can then be subjected to more detailed examination using sampling and analytical techniques of high precision and accuracy.

The Process Measurements Branch (PMB) of the Industrial Environmental Research Laboratory (IERL) of EPA at Research Triangle Park, N.C., has developed a cost-effective approach for sampling and analysis of all waste streams (air, water and solid). Two detailed documents have been written which clearly spell out sampling⁴ and analysis⁵ protocols which maximize emissions information. These documents should serve as basic references for design of future IERL field test programs.

The approach taken is a so-called multilevel phased approach. The first step, Level 1, involves sampling of all process effluent streams for gaseous, liquid and solid components. For ducted air streams, particulates are collected in three size fractions by a series of cyclones. Liquid material is either condensed or captured in impingers. Gaseous organic species are adsorbed in a porous polymer trap containing Tenax resin. Fugitive emissions are sampled with hi-vol filters and portable gas chromatographs.

Level 1 sampling provides a single set of samples to represent the "average" composition of each stream. The analytical techniques for Level 1 have been kept as simple as possible to minimize cost, consistent with the goal of identifying all waste stream constituents having the potential for contributing to environmental deterioration. Physical and biological assay tests are incorporated into Level 1 analysis. Inorganic analysis at Level 1 utilizes spark-source mass spectrometry (SSMS) for qualitative and semiquantitative analysis of all solids collected whether as solids, particulates or residues from evaporated liquid samples. Some 80 elements can be analyzed with a precision and accuracy within a factor of 2 and a detection limit of 1 ppm at nominal cost (~\$300 per sample).

An additional analytical goal of Level 1 is the identification of all organic functional groups present in amounts greater than 0.1 to 1 μg . This analysis is accomplished by extraction of each sample in a suitable solvent(s), separation of the extract into eight fractions by liquid chromatography and identification of functional groups present in each fraction by infrared spectroscopy.

Once Level 1 procedures are completed the information is evaluated to determine which waste streams must be subjected to more extensive sampling and analysis (Level 2) to identify specific compounds. Although Level 2 sampling is not significantly different from Level 1 technique, the analytical techniques employed for specific compound identification are considerably more sophisticated and thus more expensive. Techniques used include atomic absorption, X-ray fluorescence and neutron activation analysis for trace elements and nuclear magnetic resonance, gas chromatography mass spectrometry, high performance liquid chromatography and high resolution mass spectrometry for organics.

The philosophy behind this phased approach is that Level 1, which is relatively inexpensive, is a screening step which serves two major purposes. Based upon total emission mass loadings or absence of significant concentrations of elements of organic functional groups certain waste

streams may be judged acceptable and therefore eliminated from further study. The alternative guidance to be gained from Level 1 results is an indication of which specific pollutant compounds should be sought by the Level 2 procedure, thus avoiding the time and expense of analyzing for every conceivable element or compound.

The principal argument for adopting this IERL approach to a test program is that the precise uniformity of the sampling and analysis procedures makes the results derived from different processes directly comparable in terms of mass loadings and emissions rates of pollutants.

A number of proposed or ongoing programs are using the phased approach in studies of effluents from combustion sources. While most of these are specific to air emissions the previously mentioned proposed EPA program (RFP DU-76-A106) will involve phased sampling and analysis of all waste streams from 54 of the 56 combustion systems studied in the preliminary emissions assessment program. Monsanto Research Corporation is already conducting a phased study of the remaining two combustion systems. A few representative programs are listed below.

- Organic and Sulfate Sampling Analysis at Colbert Steam Plant (GCA/Technology Division, EPA Contract No. 68-02-1316, Task Order No. 21, EPA Project Officer Dr. Ronald A. Venezia, IERL/RTP)

The above contract is part of a comprehensive sampling and analysis program at the Colbert Steam Plant of the TVA. This joint effort will include feedstock, water, solid waste and flue gas sampling by TVA personnel, particle size distribution measurements by Midwest Research Institute and determination of sulfates, polynuclear organic matter, polychlorinated biphenyls and particulate and vapor phase organics by GCA under EPA sponsorship. TVA will conduct extensive chemical analysis, especially for metals, in all coal, water and fly ash samples including the size fractions collected by MRI. The IERL Level 1 sampling train will be used in this study. The final report is due August 30, 1976.

- Engineering and Technical Services Contract
(RFP CI 76-0238, IERL/Cincinnati, CBD 5/13/76)

About 15 contracts will be awarded under this general contract. The contracts will be to perform quick-response requirements in various areas including pollution control, energy systems, fuel technology, water pollution, solid waste management, toxic substances, emissions surveys, etc. As of the date of this report no RFP has been issued. While emission measurement will not be a major portion of the total program activity, some combustion system emission measurements, particularly of water emissions and solid waste, will be conducted.

- Nonpersonal, Quick-Reaction Engineering and Technical Services (EPA RFP DU-76-A107 Proposal Due Date 4/26/76)

This quick-response service contract will involve activities in the pollution control, energy and emissions assessment areas which will be applicable to conventional stationary combustion sources.

- Integrated Technical Assessment of Electric Utility Energy Systems (EPA, Washington Contemplates Negotiations With Teknekron Inc., Berkley, California, CBD 5/12/76)

SECTION IV

FLUE GAS EMISSIONS - GENERAL

The growing emphasis on the need to characterize waste streams in such a way as to identify all potentially harmful pollutants was noted in Section III. Many recent and proposed EPA programs to sample and analyze flue gas emissions also call for this comprehensive approach, often based on the multilevel phased approach. In addition to the screening of many trace elements and anions, emphasis is being placed on organic compounds such as POM, PCB and Nitrosamines.

Nitrosamines, a class of known carcinogens will be studied in several new IERL-RTP in-house and contract activities. Programs include instrumentation development, air and water sampling, and health effects studies. The interest in nitrosamine has been prompted by recent measurements of alarming concentration in both air and water on the East Coast. Nitrosamines, for which NO_2 is a precursor, may be responsible for the observed correlation between NO_2 levels in urban areas and the high incidence of cancer.⁶

The identification of anions such as sulfates, nitrates, chlorides, fluorides, etc., has been a major activity of many EPA programs. Although no programs have been concerned to any extent with sulfite ion, per se, a recent study⁷ conducted for the Electric Power Research Institute by Anthony V. Colucci of Greenfield, Attaway and Tyler Inc. and D.E. Eatough, Director of Brigham Young University's Center for Thermochemical Studies hypothesizes that sulfites, rather than SO_2 or sulfates, could be of most significance to human health. The study indicates that sulfites form

stable compounds with trace metals in the fine particulate fraction of flue gases. The study findings, which EPRI terms as only suggestive, would have implications for flue gas desulfurization since scrubber technology is not effective for fine particulate collection, and would be of limited value in collection of trace metal sulfite compounds.

Fine particulates remain an area of major concern because of their respirable nature and the tendency of potentially hazardous components (such as sulfites) to concentrate on their surfaces.^{8,9} Concern over fine particulate emissions and the poor performance of electrostatic precipitators on emissions from low-sulfur fuels has sparked interest in fabric filter collectors within EPA and industrial manufacturers of pollution control equipment. Almost all control equipment manufacturers are predicting a surge of sales for fabric filters for utility and industrial boilers.

Some of the following programs, in addition to those described in previous sections, have been identified as programs whose emphasis is on a comprehensive analysis of flue gas emissions. Programs which are concerned with NO_x control through combustion modification are discussed in Section II and in the following Section V. The programs cited undoubtedly represent only a small fraction of current and planned program activity.

- Study to Evaluate the Emissions From Stoker Coal-Fired Boilers and to Investigate Potential Methods of Environmental Improvement for Their Effluents (EPA RFP No. DU-76-A175, Proposal Due Date 6/21/76)

This proposed program of 27 months duration will characterize the spectrum of emissions from industrial coal-fired stoker boilers and will investigate methods to reduce these emissions. Initial efforts will be directed at evaluation of emissions from a small-scale stoker firing untreated, reconstituted, and processed coals. The potential for emission control will be studied. Following tests on the small-scale unit, testing will be continued on a full-scale industrial stoker boiler to evaluate the effects of fuel and combustion modifications.

The program calls for Level 1 comprehensive sampling and analysis (CSA) followed by Level 2 CSA as appropriate to identify all potentially important pollutants.

- Determine the Concentration, Size Distribution, and Physical and Chemical Characteristics of Particles Between the Boiler Exit and the Stack as Well as in the Plume, and Investigate the Relationship of These Particles to Possible Occurrences of Fallout (Southern California Edison, RFP U046048, Proposal Due Date 6/16/76)

This proposed program of 16 months duration is scheduled for completion by November 1977. The work will consist of a comprehensive analysis of particulate and particulate related emissions from oil-fired steam electric generating stations. Parameters to be studied include particle concentration, particle size distribution, particle physical and chemical properties and possibly related phenomena such as metallic catalysis, sulfate and aerosol formation, particle agglomeration and acid smut fallout. The determination of the reasons for and the identification of corrective measures for acid smut fallout are the principal program objectives.

- Field Testing: Application of Combustion Modification to Control Pollutant Emissions From Power Generation Combustion Systems (Exxon Corporation, EPA Contract No. 68-02-1415, Project Officer, Robert E. Hall, IERL/RTP)

The ongoing Exxon field test program of utility power generation equipment has been extended to include trace emission measurements and the testing of an additional six units. Under this extension analyses will be made of sulfates, nitrates, HCN, HCl, POM and PCB and trace metals. In addition to reporting the total POM, the contractor shall report total POM as percent of particulate. This augments the original measurements of NO, NO₂, SO₂, SO₃, CO, HC, particle loading and size distribution. The additional units may include cyclone and wet bottom wall-fired boilers, gas turbines with water injection, internal combustion engines with precombustion chambers, and utility boilers firing waste fuel or using fuel additives. Corrosion tests are planned for one utility boiler to test the effects of NO_x controls over a 6-month period.

- Field Testing of Industrial Process Equipment, Gas Turbines, and Internal Combustion Engines (KVB Engineering, EPA Contract No. 68-02-2144, Project Officer, Robert E. Hall IERL/RTP)

This 1 year field test program is intended to provide detailed emission characterization of a representative group

of combustion equipment firing coal, oil, gas, waste fuels and mixed fuels. Measurement will be made of NO, SO₂, SO₃, CO, HC, particulate size fractions, opacity and, where relevant, trace metallics and organics (POM, PCB). Modification of operating parameters such as load, excess air and combustion air preheat will be studied. Water injection, as a means of controlling NO_x from gas turbines, may be assessed. A total of 25 units will be tested.

The following planned or recently awarded contracts, as noted in the Commerce Business Daily, also appear to apply to the study of flue gas emissions from conventional stationary combustion sources.

- Sampling and Analysis Methods for POM and Other Organic Pollutants (EPA Contract No. 68-02-2150 (DU-75-A220) for \$899,272 - to Arthur D. Little, Acorn Park, Cambridge, Mass. 02140, CBD 4/2/76)
- Investigation and Feasibility Study of Methods for the Identification and Measurement of Inorganic Compounds Emitted as particulates from sources using or processing fossil fuels (EPA Contract No. 68-02-2296 (DU-75-B180), for \$240,195 - to Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio 43201, CBD 4/2/76)
- Trace Element Emission as Function of Particle Size From Coal-Fired Steam Plant (EPA Contract No. 68-01-3702 (WA 75-R367) - \$108,310 - Radian Corp., P.O. Box 9948, Austin, Texas 78766, CBD 4/26/76)
- Field Testing of Advanced Industrial Boiler Designs. (Letter Amendment 3, Contract No. 68-02-2144 (CU-76-A138) \$87,500 - KVB, Inc., 17332 Irvine Boulevard, Tustin, Ca. 92680, CBD 4/26/76)
- Measurement of POM Emissions (EPA RFP DU-76-B164, CBD 6/9/76)

EPA expect to award a contract to Battelle, Columbus to evaluate POM sampling and analytical procedures at selected sources.

- Study of Stationary Source Sulfate Emissions (FPC Intragency Study)

This is a proposed 2-year, \$1.5 million study of sulfate emissions from stationary combustion sources. The study

reportedly to involve funding from four other federal agencies in addition to FPC, would be designed by a committee selected by the National Academy of Sciences.

If the study receives the anticipated funding from the federal agencies, contracts would be awarded, under the FPC proposal, in January 1977, field studies and laboratory testing would be completed a year later, and field work, inventories, and modeling would be completed by January 1979.

The study would identify "major operating parameters and variables" of a combustor affecting sulfur trioxide emission concentrations. It would indicate a "standard procedure for determining emission inventories of combustor SO₃ emissions," according to the FPC proposal.

Combustion devices with "similar emission factors" would be categorized under the proposed program, and the researchers would indicate variations in SO₃ emission concentrations for various combustion systems using low-sulfur fuels. The researchers also would "re-evaluate the contribution of urban stationary fossil fuel sources to the past and present ambient sulfate burdens."

SECTION V

FLUE GAS EMISSIONS - NO_x

This section covers activities and programs which are principally concerned with the control of NO_x from stationary combustion sources. Several programs concerned with NO_x control have already been cited in previous sections, particularly Sections III and IV.

Current methods of NO_x control emphasize combustion modification (e.g., low excess air, overfire air, fuel gas recirculation, biased firing to achieve Federal New Source Performance Standards of 0.7 lb NO₂/10⁶ Btu (0.301 mg NO₂/J) for coal. According to Power Magazine's annual plant design report¹⁰ nearly half of the 52 new utility boilers surveyed will use over fire air ports to achieve compliance. Several of the new plants are expecting to meet the standard using only low excess air firing. This capability is strongly dependent upon the combustion characteristics and the nitrogen content of the coal fuel. A number of the new units will reportedly use flue gas recirculation for NO_x control. This practice will bear scrutiny since flue gas recirculation has been ineffective in many small scale and full scale tests.³

In addition to NO_x control measures based on combustion unit modification, other techniques now being studied by IERL/RTP, EPRI and others include flue gas treatment (FGT) and injection of additives. The major concepts for NO_x FGT studied to date are: catalytic decomposition, selective or nonselective catalytic reduction, absorption by scrubbers, and adsorption.³ Catalytic decomposition is thermodynamically favored but is hopelessly slow for known catalysts. Catalytic reduction of NO_x appears attractive

for supplementing combustion process modifications in the 1980's. Areas under study include selective reduction by ammonia and nonselective reduction by CO or H₂. Catalyst lifetime when exposed to effluents from coal combustion is of major concern. Absorption by agents such as KMnO₄, Na₂SO₃ and NaClO₂ has been extensively studied, particularly in Japan where stringent NO_x controls are in effect. These processes typically oxidize the NO to the more readily absorbed NO₂. The major concerns here are the high cost and the environmental impact from the liquid and solid wastes. Adsorption of NO₂ by molecular sieves is widely practiced in nitric acid plants. This concept requires dry effluents and is inappropriate to combustion sources.

Exxon has patented a concept for NO_x reduction of selective reaction with ammonia which shows promise for supplementing combustion modification techniques. The patent cites test data obtained from a bench scale flow reactor in which NO_x reduction in excess of 90 percent were obtained in some cases. Adequate NO_x reduction is based on the depletion of flue gas oxygen usually through the addition of hydrogen or hydrocarbons.³ To date, no demonstration tests on field equipment have been reported. Of particular interest would be the effectiveness and total environmental impact of ammonia injection in the effluent from a coal-fired unit. The inventor is Richard K. Lyon, Exxon R&E, Linden, N.J. Reference: U.S. Patent 3,900,554, August 19, 1975.

The reduction of NO_x from internal combustion engines has involved both dry and wet (water injection) techniques. While wet techniques have been successful in achieving present regulatory levels, dry techniques are receiving greater emphasis.

A novel approach to NO_x control in combined gas turbine/steam boiler systems has been developed by KVB Engineering under contract to EPRI.³ The boiler downstream of the gas turbine is fired fuel-rich using approximately 80 percent of the NO_x bearing gas turbine exhaust as the combustion air.

The remaining gas turbine exhaust provides the boiler second stage air which is injected through over fire ports above the fuel rich primary stage. This use of overfire air effectively reduces the NO_x formed in the boiler by up to 50 percent. The novel aspect of the KVB tests is that up to 55 percent of the NO_x in the simulated gas turbine products was chemically reduced in the fuel rich primary stage of the boiler. The total NO_x emissions from the combined cycle may, in certain conditions, actually be less than that from the gas turbine alone. The practical significance of the KVB results are: (1) combined cycles in which the boiler is supplementary fired may be operated at acceptable NO_x levels without water injection into the gas turbine, and (2) existing steam plants can be updated in capacity by repowering with a gas turbine without substantially increasing NO_x emissions.³

Following are descriptions of a few significant NO_x control program which have been recently completed and form the basis for much of the present activity in this area.

- Field Testing: Application of Combustion Modifications to Control Emissions From Industrial Boilers - Phase I and II. (KVB Engineering, Tustin, California, EPA Contract No. 68-02-1074, Project Officer - Robert E. Hall, IERL/RTP)

KVB Engineering has completed a 1-year EPA emission characterization field test of packaged and field erected industrial boilers in the size range 4,500 to 225,000 kg (10,000 to 500,000 lb) steam/hr. Forty-seven boilers encompassing 75 combinations of boilers/burners/fuels were tested to yield a representative sample of the industrial boiler field population. All major fuels - gas, distillate and residual oil, and pulverized or stoker coal - were tested. Limited study was made of the degree of control achievable from fine tuning of excess air level, unit load, burner adjustment, and, where possible, biased burner firing, burner swirl, and overfire air. In comparison to utility boilers, industrial boilers were found to have limited flexibility for NO_x control through minor modification of operating conditions.

The range of uncontrolled base load NO_x emissions for the 47 test boilers was 224 to 800 ppm, 100 to 619 ppm, and 50 to 375 ppm for coal, oil and gas firing, respectively.

In the NO_x control tests, low excess air firing was shown most effective for coal-fired stokers and oil-fired water-tube boilers. The firetube boilers and gas-fired water-tube units generally showed less response to low excess air (LEA) firing. For multiburner units, off-stoichiometric combustion was achieved by biasing burner stoichiometry or by taking burners out of service. This yielded NO_x reductions up to 40 percent. For stokers, off-stoichiometric combustion was achieved by modification of existing overfire air ports. This resulted in NO_x reductions up to 25 percent.

Results from a second phase of the KVB survey are now published. The Phase II effort applied more extensive control techniques to a smaller number of units.³

- Field Testing: Application of Combustion Modification to Control Pollutant Emissions From Power Generation Combustion Systems (Exxon Corporation, EPA Contract No. 68-02-1415, Project Officer Robert E. Hall, IERL/RTP)

In previous work on this contract, sponsored jointly with EPRI, Exxon tested six coal-fired utility boilers and a gas turbine. Tests with the new Babcock and Wilcox dual register controlled diffusion flame coal burners showed a 35 percent NO_x reduction relative to conventional burners. Use of overfire air ports and low excess air on a coal-fired tangential unit gave over 50 percent NO_x reduction compared to normal operation. Mixed fuel tests showed that addition of a small amount of gas to a coal-fired unit gas a disproportionately large decrease in NO_x emissions. Emissions with mixed coal and nitrogen bearing oils were roughly proportional to the mixture of the fuels. Short term corrosion probe tests were made on a tangentially-fired and a wall-fired unit equipped with NO_x controls. No significant difference in corrosion rate was observed with low NO_x operation. The long term tests cited in Section II of this report will be studied further.³

- Biased Firing Tests - TVA Interagency study with EPA, (Project Officer, David G. Lachapelle, IERL/RTP)

In this interagency study, biased burner firing was tested on a 125 MW single-wall coal-fired B&W utility boiler. The unit was tested with variable load, variable excess air level, and several biasing patterns for the square 16-burner array. Measurements were made under baseline and controlled operation for gaseous and particulate emissions, boiler tube wastage, and boiler efficiency. As expected, biasing was most effective for NO_x control when the top of burners was operated on air

only. NO_x reductions of 30 to 50 percent were found over the range of loads and excess air studied. A small decrease (1 percent) in boiler efficiency with biasing was attributed to increased carbon loss in the stack under controlled operation. Potential tube corrosion due to the reducing atmosphere in the lower furnace with biasing was assessed by comparison of tube wastage rates under normal and controlled operation. Preliminary results show an increased corrosion potential on the side walls. Long term tests are needed to quantify the effect and, if necessary, to identify corrective measures.³

- Effect of Overfire Air Retrofit on NO_x Emissions From Tangential Coal-Fired Utility Boilers (Combustion Engineering, EPA Contract No. 68-02-1307)

Retrofit overfire air ports were installed and tested by Combustion Engineering, under contract to EPA, on an Alabama Power Company 125 MW tangential coal-fired utility boiler. The ports were installed in each corner approximately 2.5 m (8 feet) above the top fuel nozzle. The unit was tested at the normal baseline condition, with biased firing and with overfire air (OFA). Variables included percent air to the fuel firing zone, load, total excess air, level of slag buildup on the boiler tubes, and the tilt of the overfire air ports and fuel nozzles. Baseline tests at 20 to 25 percent excess air showed compliance with the NO_x standard of performance for new stationary sources of 301 ng NO_2/J (0.7 lb/10⁶ Btu). Operation below 20 percent excess air (EA) was precluded by increasing CO emissions. The baseline tests showed a negligible effect on NO_x emissions of unit load or slag buildup on the tubes. This may mean that the NO_x emissions are due predominately to conversion of fuel nitrogen which is known to be relatively insensitive to firebox temperatures. Biased firing with the upper fuel nozzle operated on air gave approximately 50 percent NO_x reduction relative to the normal condition. Operation with the fuel firing zone air at 95 percent of stoichiometric was achieved with no increase in CO. Biased firing with the lower fuel nozzles on air showed negligible NO_x reduction.

Tests with the retrofitted overfire air system gave up to 40 percent NO_x reduction with the firing zone at 95 percent of stoichiometric. Operation below 95 percent gave no additional NO_x reduction. The distance between the OFA ports and the firing zone was varied by taking either the upper or lower fuel nozzle out of service. OFA was most effective at the maximum separation from the firing zone. The effect of OFA tilt with respect to the fuel nozzle tilt was studied by varying the total differential tilt angle through ± 50 degrees from the horizontal. NO_x emissions decreased as the

OFA was tilted away from the fuel. A 25 percent reduction relative to horizontal was shown at + 50 degrees differential tilt. Further tilt was precluded by flame instabilities and increasing carbon monoxide.³

SECTION VI

WATER POLLUTION SOURCES, SOLID WASTE, AND MISCELLANEOUS POLLUTION SOURCES

Very little information has been obtained regarding water pollution from stationary combustion sources. Lack of available data is attributable to the site specific nature of water emission streams in contrast to air emissions where emission factors can be applied with reasonable accuracy given certain information regarding fuel type and consumption rate, boiler type and control equipment.

Solid waste programs have emphasized solid waste generated by flue gas desulfurization systems rather than ash as collected by particulate control devices. The basic problems are similar though amplified by flue gas desulfurization (FGD) systems due to the greater volume potential, higher solubility of trace elements and reactant liquor components such as sodium, and the generally poorer physical properties of the nonregenerable sludges.

The following planned or recently awarded contracts are concerned with waste disposal and certain aspects of water pollution, treatment or usage within combustion systems.

- Study of Utilization of FGD Gypsum in Portland Cement (Negotiations are contemplated only with the South Carolina Public Service Authority, Moneks Corner, SC, on the basis of their unsolicited proposal - Negotiation No. DU-76-A199, CBD 5/24/76)
- Evaluation of Alternatives for the Disposal of Flue Gas Desulfurization Sludges (EPA RFP DU-76-A133 - EPA contemplates negotiations with Arthur D. Little, Inc., Cambridge, Mass. for changes to the present effort being performed under existing Contract No. 68-03-2334, CBD4/9/76)

- Study of Disposal of By-Products for Nonregenerable Flue Gas Desulfurization Systems (The Aerospace Corp. Los Angeles, California. EPA Contract No. 68-02-1010, Mod. No. 4 \$500,000)

- Assessment of Technology of Disposal and Utilization of Flue Gas Cleaning By-Products (EPA RFP DU-76-A127)

This proposed (proposal due date 7/19/76) 36-month program involves a review of previous EPA contract efforts. Contracts to be reviewed are outlined in the RFP and presented in Table 1.

- Comparative Toxicologic Assessment of Fly Ash From Western U.S. Eastern Coals (EPA Contract No. 68-02-7390 (RFP CI 75-0201). CBD 6/16/76). A \$318,000 contract awarded to Huntingdon Research Center, Brooklandville, Md.
- Study of the Mineral Matter Distribution in Pulverized Fuel Coals with respect to slag formation in boiler furnaces. (EPA Contract E(49-18)2316 for \$192,431 to Pennsylvania State University, Philadelphia, Pa. U.S. Energy Research and Development Administration, Washington, D.C. 20545, CBD 4/76)
- Chemical and Physical Factors Affecting the Retention of Radionuclides in Soil and Rock Materials - A Critical Review (EPA RFP CI 76-0182, CBD 5/76)

The proposed study necessitates careful review and synthesis of the available soil physics, soil chemistry, and mineralogy literature base documenting the interaction of radionuclides and soil/rock materials. At present, the contents and significance of hundreds of key studies generally are unavailable to management in industry and government, and to leading environmental groups. Information gained from the study will assist the Agency in reviewing the environmental impacts of activities.

- Treatment of Flue Gas Waste Streams with Vapor Compression Cycle Evaporation (EPA RFP DU-76-A196, CBD 6/8/76)

EPA plans to issue a contract to Resources Conservation Co. Renton, Washington to assess the treatment of waste stream blowdown from a Chiyoda FGD system.

- Evaluate the environmental acceptability and economics of leachate collection and treatment systems (EPA RFP WA 76-B115, CBD 6/8/76)

- Effects of Pathogenic and Toxic Materials Transported Via Cooling Tower Device Drift (EPA RFP DU-76-A185, CBD 5/19/76)

The Environmental Protection Agency (EPA) is seeking a contractor to perform research on the above subject. A level of effort of 2,500 technical labor hours is planned. Increasing use of cooling devices (i.e., towers, sprays) in industrial recycle programs has resulted in the reuse of relatively poor quality water. Cooling, device drift (e.g., droplets of cooling water transported beyond the confines of the cooling device) may therefore contain toxic materials and/or pathogenic organisms.

A study is required to assess the potential effects of the possible toxic material and pathogenic organisms in cooling device drift on plants and animals, including humans. This work will require the identification of the types of organisms and toxic substances potentially present in drift, their fate during the atmospheric transport of the drift particle, and their potential effects upon contact with the plants or animals. The possibility of transporting disease to humans via affected plants and animals will be considered. Statements regarding the probability of the potential effects will be given. All study results and conclusions will be presented in the final report.

- Evaluation of Clay Liner Materials Exposed to Landfill Leachate (EPA RFP WA-76-B125, CBD 6/2/76)

Negotiations with Emcon Assoc., San Jose, California.

- Environmental Effects and Control of Various Flue Gas Cleaning Sludge Disposal Operations (EPA RFP CI-76-0258, CBD 6/2/76)

Firms are being sought to evaluate available technology and economics and establish an understanding of impacts associated with sludge disposal.

- Mechanism of Fly Ash Formation in Coal-Fired Boilers, (ERDA E(49-18)-2205, \$224,000, CBD 3/26/76)

Table 1. PROJECTS IN IERL/FGC^a WASTE AND WATER PROGRAMS^b

Project title	Contractor/Agency	Ongoing	Project status		Planned
			CV 75 Start	In negotiations	
Disposal/Utilization of Flue Gas Cleaning By-Products: Technology Assessment and Transfer	Contractor Selection Pending				X
Disposal of By-Products From NonRegenerable Flue Gas Desulfurization Systems 68-02-1010	The Aerospace Corporation	X			
Shawnee FGD Waste Disposal Field Evaluation	Tennessee Valley Authority	X			
Louisville Gas and Electric Evaluation of FGD Waste Disposal Options	Louisville Gas and Electric Company (Subcontractor: Combustion Engineering)			X	
Lime/Limestone Wet Scrubbing Waste Characterization	Tennessee Valley Authority		X		
Lab and Field Evaluation of 1st and 2nd Generation FGD Waste Treatment Processes	U.S. Army Corps of Engineers Waterways Experiment Station	X			
Characterization of Effluents From Coal-Fired Power Plants	Tennessee Valley Authority		X		
Ash Characterization and Disposal	Tennessee Valley Authority		X		
Studies of Attenuation of FGC Waste Leachate by Soils	U.S. Army Material Command Dugway Proving Ground	X			
FGD Waste Leachate-Liner Compatibility Studies	U.S. Army Corps of Engineers Waterways Experiment Station		X		
Establishment of Data Base for FGD Waste Disposal Standards Development	SCS Engineers, Inc.		X		
Conceptual Design/Cost Study of Alternative Methods for Lime/Limestone Scrubbing Waste Disposal	Tennessee Valley Authority		X		
Evaluation of Alternative FGD Waste Disposal Sites 68-03-2334	Arthur D. Little, Inc.		X		
Gypsum By-Product Marketing Studies	Tennessee Valley Authority		X		
Lime/Limestone Scrubbing Waste Conversion Pilot Studies	M.W. Kellogg Company			X	
Fertilizer Production Using Lime/Limestone Scrubbing Wastes	Tennessee Valley Authority		X		
Assess/Demonstrate Power Radian Corporation Plant Water Reuse/Recycle	Radian Corporation				
Dewatering Principles and Equipment Design Studies					X
Use of FGD Gypsum in Portland Cement Manufacture	Contractor Selection Pending				X
FGD Waste/Fly Ash Beneficiation Studies					X

^aFlue gas cleaning.

^bRFP DU-76-A127, Assessment of Technology of Disposal and Utilization of Flue Gas Cleaning By-Products.

SECTION VII

FUELS

Total energy use in the United States was down in 1975 for the second year in a row according to recently released Bureau of Mines preliminary figures.¹¹ The biggest factor in the net decline was a 6 percent downturn in the industrial sector and 2 percent reductions in the commercial and residential sector. Electric utility fuel use was up 0.6 percent. Consumption of bituminous coal and lignite increased 1.7 percent while anthracite and natural gas fell 7.8 and 7.2 percent respectively. Petroleum was down 1.9 percent while nuclear power jumped 37.5 percent in 1975.

Despite the slowdown in fossil fuel combustion the Federal Energy Administration (FEA), in an updated version of its Project Independence blueprint, forecast an annual growth rate of 5 percent in coal consumption reaching 1,040 million tons in 1985.¹² This projection is 100 million tons less than FEA's 1974 projection.

FEA's report calls for 5.7 percent annual growth in electric utility coal use between now and 1985 with utility use climbing to 759 million tons. In 1974, utility use was 388 million tons. Industrial use will be 124 million tons in 1985 as compared with 64 million tons in 1974. Coke and gas use will rise to 100 million tons from 90 million tons in 1974. Coal use in synthetic fuels will grow from zero to 16 million tons. Exports will rise to 80 million tons from 60 million in 1974.

Bulk of the increased production the FEA report predicts will come from the West. It says over half of the production will come from one region -

the western Northern Great Plains and an additional 25 percent from one other region - Central Appalachia.

The forecast sees the ratio of surface production to total production increasing from about 54 percent to 63 percent "because nearly all western production which is forecast to grow rapidly, is surface-mined."

Specifications for new sales in utility and industrial boilers, pollution control equipment and support equipment were recently provided.¹⁰ Eighty percent of new utility boilers scheduled for application in 1976 to 1980 will use coal as the primary fuel. This compares to 42 percent coal-fired in a comparable 1971 survey. Gas as a primary fuel is down to 7 percent as compared to 32 percent in the 1971 survey. Design furnace heat release rates are down from prior years due primarily to increased use of low heating value, low sulfur western fuels. From a SO_x emission standpoint the lower sulfur content of western coals is offset by the lower heating value. In general however, conversion to western coal yields a substantial reduction in SO_x emissions and affords compliance with NSPS or $1.2 \text{ lb SO}_2/10^6 \text{ Btu}$ ($0.516 \text{ mg/O}_2/\text{J}$) without further control. Conversion to western coals could, in some cases, give higher NO_x emissions, due to the higher nitrogen content of western coals.¹³

Of U.S. coal reserves, 46 percent are in the west. Over 80 percent of the western coal has less than 1 percent sulfur content. Western coal production was 53 million metric tons in 1973 and is expected to increase by over a factor of eight by 1985.¹³

The prime drawback of conversion to western coal in boilers is the unit derating which results from the lower heating value. This is primarily due to limitations in the coal feed system. User experience has also shown a higher carbon loss with western coals. Electrostatic precipitator collection efficiency is typically decreased with western coals due to the low sulfur content and resulting high resistivity of the fly ash. Stoker-fired industrial boilers, particularly traveling grate spreader

stokers, appear to be an attractive relatively trouble-free application for conversion to western coal.¹³

The anticipated growth in coal combustion has spurred interest in flue gas desulfurization and other means of sulfur removal and trace metal and fine particulate control measures. A program to determine precisely the composition of coal and identify toxic elements released into the environment from coal development has been expanded by the U.S. Geological Survey. Included will be the accurate determination in percentage or parts per million of the 50 to 70 elements detectable in coal in major, minor, or trace amounts - for example, sulfur, arsenic, mercury, beryllium, fluorine, cadmium, selenium, and zinc. About 2500 coal samples already have been collected and analyzed, and data are being entered into USGS's National Coal Resources Data System. The agency expects to be able to perform more than 1500 analyses per year.¹⁴

While the debate over flue gas desulfurization (FGD) continues between government and industry work is progressing on other methods of removing sulfur from coal prior to combustion. A final report of a Department of Commerce study panel to identify the most economical means of achieving continuous SO_2 control on coal-fired electric utility plants in the Northeast concluded that coal beneficiation or washing alone can achieve certain regulatory levels.¹⁵ In more stringently controlled areas beneficiation followed by some measure of FGD can improve the economics over the use of FGD alone. The coal beneficiation techniques considered by the panel are those now available, not the advanced technologies being investigated by Battelle and others.

Because of the petroleum and natural gas shortages many utilities will be forced to convert to coal. For those plants which have already undergone a conversion from coal, reconversion may be relatively simple if the auxiliary equipment is available or can be reinstalled. However, in many instances conversion to coal may be costly or even impossible. The Energy Research and Development Administration is soliciting contracts to

demonstrate coal/oil slurry combustion in existing steam generator and industrial process equipment.³ Coal/oil slurries can be fired in a boiler equipped for oil firing with only minor modification. It is thus seen as an attractive means of coping with the dwindling supply of oil while avoiding the costly conversion to coal firing. In small units, where a coal feed system would be prohibitively expensive, coal/oil slurries afford a low-cost method of coal utilization. Equipment categories considered by ERDA for the 2-year demonstration program are blast furnaces, utility and industrial steam generators originally designed for gas or oil, utility and industrial steam generators originally designed for coal but subsequently converted to gas or oil, and industrial process/direct fired process heaters. ERDA will also consider bids for a mixing and distribution facility to supply coal/oil slurries to multiple users from a central location.

The following planned or recently awarded contracts, as noted in the Commerce Business Daily, appear to apply fuel technology as related to emissions from conventional stationary combustion sources.

- Preparation of a Second Supplement to the Text Chemistry of Coal Utilization, (ERDA E(49-18)2282 National Academy of Sciences, CBD 4/76, \$285,000)

This program involves a critical review of the current state-of-the-art of coal chemistry and technology (1960 to present) and to prepare and publish a comprehensive self-contained text which would be supplemental to two previous books (1945 and 1963).

- Select, Modify and Develop Coal Grinding Equipment and Procedures for the Coal Conversion Industry. (ERDA is now conducting negotiations with Kennedy Van Saun Corp. Danville, Pa. CBD 6/17/76)
- Research to Determine the Catalytic Activity of Naturally Occurring Mineral Matches in Coal in Recovery Sulfur and Nitrogen (\$108,000 to University of Kentucky Research Foundation, ERDA E(49-18)-2229, CBD 3/25/76)

SECTION VIII

CONTROL OF FLUE GAS EMISSIONS

Flue gas control devices are often used to control emissions of particulates and SO_2 from large combustion sources, and particularly coal-burning sources. The impending growth in the combustion of low-sulfur fuels, partly to avoid the need for flue gas desulfurization systems, has resulted in a decrease in the efficiency of electrostatic precipitators, the conventional particulate control device used by utilities and industry. Although efficiencies can be upgraded by redesign or hot-side usage (or the use of conditioners) the cost of this upgrading is appreciable. Because of the unfavorable economics associated with high efficiency ESP design and the need for even higher efficiency collection of fine particulates, there has been a surge of interest in the use of fabric filters as particulate control devices for combustion sources. Almost every manufacturer of control equipment is cognizant of this potential shift in particulate control from the ESP to the fabric filter, and in-house programs are ongoing to prepare for this eventuality.

Flue gas desulfurization (FGD) systems continue to receive major attention and remain the focus of controversy among EPA, utilities and other potential FGD users. Papers presented at an EPA-sponsored FGD symposium held March 8-11 in New Orleans pointed to improved reliability and availability of scrubbers and the emergence of double alkali technology as an alternate to lime/limestone scrubbing processes. According to PEDCo - Environmental Specialists some 109 FGD systems having a total equivalent rating of over 42,000 megawatts are operational, under construction or planned. PEDCo's analysis of FGD systems in the United States is shown in Tables 2 and 3.

Table 2. FLUE GAS DESULFURIZATION SYSTEMS IN THE U.S., JANUARY 1976

Status	Number of units	MW
Operational	21	3,796
Under construction	20	7,026
Planned		
Contract awarded	10	3,761
Letter of intent	10	3,911
Requesting or evaluating bids	7	3,837
Considering FGD systems	40	19,797
Total	109	42,128

Table 3. FLUE GAS DESULFURIZATION PROCESSES IN THE U.S.

	MW ^a 1976	MW 1980
Limestone	4,077	11,221
Lime	3,442	7,716
Sodium carbonate	375	375
Magnesium oxide	365	1,091
Wellman-Lord	115	1,830
Cat-Ox	110	110
Lime/limestone	30	1,740
Dilute acid	23	23
Activated carbon	20	20
Dual alkali	20	20
Total	8,577	24,416

^a FGD megawattage for which a process has not been selected is not included.

Note: In 1976, about 65 percent of FGD megawattage will be retrofit, and about 35 percent will be on new plants. By 1980, 30 percent and 70 percent will be retrofit and new installations, respectively.

Source: PEDCo

Despite the continued controversy regarding FGD systems there is agreement that conventional systems are ineffective collectors of fine particulates. Present EPA efforts are directed towards more efficient utilization of the energy applied to a scrubber system and the augmentation of particulate collection by condensation and other physical phenomena. As noted in Section VI EPA is also concerned about control of waste and water pollution from FGD.

The following planned or recently awarded contracts, as noted in the Commerce Business Daily, are representative of programs dealing with the control of emissions from conventional stationary combustion sources. Waste utilization activities have been described in Section VI.

- Test Program on the Magnesium Oxide FGD Process at Philadelphia Electric's Eddystone Station. (EPA RFP No. DU-76-A128, CBD 5/4/76)

EPA contemplates negotiating with Philadelphia Electric Co., of Pennsylvania. Included: (1) relocation of Philadelphia Electric's equipment from Olin Chemical's Paulsboro Acid Plant, which is being shut down, to an acid plant for which negotiations are presently taking place (2) development and implementation of a 6 to 12-month test program to characterize the operation of the magnesium oxide slurry process, and (3) system operation during the test period.

- Full-Scale Scrubber Testing and waste disposal program at Louisville Gas and Electric. (EPA Contract No. 68-02-2143 (DU-75-A202) for \$1,800,000 to Louisville Gas and Electric Co., P.O. Box 354, Louisville, Kentucky 40201, CBD 4/7/76)
- Fine Particle High-Resistivity Electrostatic Precipitator Study (EPA RFP DU-76-A182, CBD 5/21/76)

The Environmental Protection Agency proposes to negotiate with the Southern Research Institute, Birmingham, Alabama. The primary purpose of this procurement is to develop, evaluate, and prove the feasibility of specially designed particle charging system at small pilot scale. A second purpose is to develop relationships between particle properties and allowable electrical conditions in full-scale electrostatic precipitators.

- Effects of Conditioning Agents on Emissions From Coal-Fired Boilers (RFP DU-76-A204, CBD 5/20/76)

EPA plans to issue an RFP to field test three (3) sites using conditioning agents to determine the effectiveness of the agent in improving electrostatic precipitator performance and to determine the chemical composition of the gaseous and particulate emissions with and without conditioning. Limited biological testing of the emitted particulate will be conducted. Such data are necessary to assess the usefulness of conditioning agents.

- Engineering and Analytical Support for the Louisville Gas and Electric Scrubber Program (EPA RFP DU-76-A152, CBD 5/26/76)

EPA contemplates negotiations with the Radian Corp of Austin, Texas.

- Assist EPA in Solving Problems Associated with Improving Air Quality Affected by Power Plant Operations in the Most Cost Effective Manner (Energy Resources Co., Inc. Modification to EPA Contract, CBD 5/6/76)
- Environmental Control Technology in Fuel Treatment, Processing and Conversion Convectur Streams, (EPA RFP DU-75-A167, CBD 5/6/76)

This proposed contract originally scheduled for 1975 has been resolicited and is concerned with the evaluation of control technology for existing and developing technologies.

- Analysis of Thermal Decomposition Products of Flue Gas Conditioning Agents, (EPA RFP DU-76-A220, CBD 6/18/76)

A bench-scale study of combustion products of conditioning agents used to improve the collectibility of fly ash from low-sulfur coals.

- Stack Gas Reheat Assessment Study (EPA RFP DU-76-A216, CBD 6.10/76)

Assessment of stack gas technology through a survey of vendors, utilities and others with FGD expertise. Economic and reliability comparisons will be made.

- Demonstration of a High Efficiency, High Throughput Baghouse on an Industrial Stoker-Fired Boiler (EPA Contract No. 68-02-2148, \$800,000, CBD 3/26/76, Fabrics America Corp., Atlanta, Georgia)

SECTION IX

SOLID WASTE COMBUSTION

The disposal of municipal solid waste (MSW) has become both expensive and environmentally less acceptable. Since there are increasing demands on the conservation of resources and since a large portion of municipal solid waste is combustible, the recovery of energy from municipal solid waste has received considerable attention. There are currently six approaches to recovering energy from MSW.¹⁶

The number of processes in each of the six MSW-fuel utilization approaches is given below. For each process, the number of prime contractors involved in the design and construction of a process is a measure of the state of development of the process - the greater the development, the greater the number of contractors. Only processes 1 and 6 are of direct interest to this program.

Process	No. of contractors
1. Preparation of MSW as a solid fuel	23
2. Pyrolysis of MSW to a fuel gas	10
3. Pyrolysis of MSW to a fuel oil	1
4. Anaerobic digestion of MSW to a fuel gas	2
5. Fluid-bed combustion/gas turboelectric generation	1
6. Incineration of MSW with heat recovery	30

Most processes have proposed light-fraction fuel rather than such other forms as pellets and briquettes. The composition of a typical MSW light-fraction fuel is given in Table 4. The heating value of this fuel is typically 5000 to 6000 Btu/lb. A comparison of coal and a typical MSW light-fraction fuel is given in Table 5.

The process of recovering energy by burning MSW light fraction as a supplementary fuel in power plant boilers has been under investigation by the City of St. Louis and the Union-Electric Company. The results of a demonstration at Union Electric's Meramec Plant have been fairly encouraging. The prepared solid waste was burned in suspension with coal in two 125 Mw tangentially-fired boilers. At rated load, the quantity of solid waste for each boiler (equivalent in heating value to 10 percent of the coal) is about 300 tpd. Experience at the Meramec Plant has indicated corrosion is not a major problem with supplemental firing. The existing boiler combustion controls easily accommodate the variations of solid waste quantity and quality by varying the amount of coal fired in the boiler.

Electrostatic precipitator performance was tested at Meramec with and without refuse firing. Early results showed a drop in precipitator performance when refuse was added. However, additional tests have been performed to resolve uncertainties in the data, but the results have not yet been made available.

Although the Meramec unit has been reasonably successful, some potential drawbacks to the use of MSW as a supplementary utility fuel have been noted. They include the following:

- The cost of separation necessary to obtain a fuel of marginal Btu content
- The cost of transportation and handling
- The possibility of increased corrosion due to increased chloride content on the flue gases
- Slagging

Table 4. MSW LIGHT-FRACTION SOLID FUEL

Component	%
Paper	55.0
Food wastes	16.0
Yard wastes	13.7
Glass, ceramics	2.7
Plastics	1.8
Textiles	2.5
Wood	2.6
Leather and rubber	1.8
Miscellaneous	3.9

Table 5. COMPARISON OF COAL AND MSW LIGHT-FRACTION FUEL

	Coal-fired at Meramac	Typical sub- bituminous coal	MSW light- fraction fuel
Content (%)			
Moisture	10.0	21.0	18.0
Ash	9.0	6.0	14.0
Chlorine	0.05	0.04	0.07
Sulfur	3.4	0.5	0.1
As fired, Btu/lb	11,315	9,570	5,784

- The possible reduction of ESP efficiency
- The increase in the quantity of bottom ash generated by a factor of 4 to 7¹⁷
- An increase in water pollution levels for many of the pollutants evaluators so that controls for BOD, dissolved oxygen and suspended solids will probably be required.
- Potential biological problems associated with dust emissions from the processing operation.¹⁸

Despite the above drawbacks, the combustion of MSW does have the potential to supply up to 2 percent of the nation's power requirements. The potential, plus the fact that landfill requirements are greatly reduced by waste recovery, has spurred interest in solid waste combustion. A recent listing of existing or planned solid waste recovery units is given in Table 6. The units involved in steam generation would, if implemented at full capacity, account for about 75×10^{12} Btu/hr, still less than 1 percent of the 1974 fuel consumption of about $40,000 \times 10^{12}$ Btu/yr.

The following planned or recently awarded contracts, as noted in the Commerce Business Daily, deal with solid waste combustion sources:

- Air Pollution Control Technology Development for Wastes-as-Fuels Processes (EPA RFP CI 76-0173, CBD 4/9/76)

This contract shall produce an assessment of techniques and devices to be utilized in controlling air pollution resulting from the utilization of wastes-as-fuel in the generation of energy. The assessment shall include an analysis of all available data on pollutants produced by wastes-as-fuel processes. Equipment designs shall be prepared for each of several pilot-plant-scale air pollution control devices selected for detailed field investigations (investigations which shall be subsequent to this procurement). Several of these designs shall be adopted, and the devices fabricated, and actually installed at existing demonstration plant sites to be selected. The one-year operation of the devices thus installed shall be the subject of a follow-on procurement. Prospective contractors should be experienced in conducting systems studies and preliminary designs, be experienced in

Table 6. STATUS OF RESOURCE RECOVERY PLAN

Location	Processes employed								Output							Capacity, tons/day	Status reported
	Shredding	Air Classification	Mechanical Separation	Incineration	Anaerobic Digestion	Pyrolysis	Other	Utility Boiler (Steam)	Magnetic Metals	Nonferrous Metals	Paper	Class	Fuel Gas	Oil	Other Fuel		
Ames, Iowa	x	x							x	x	x					200	Operational 1975
Baltimore, Md.	x		x					x	x	x						1000	Operational
Berlin, Conn.								x	x	x						1800-2200	Planning
Beverly, Mass.								x	x	x						500-1000	Planning
Bridgeport, Conn.		x	x					x	x	x						1500	Scheduled late 1977
Chicago, Ill.	x	x						x	x	x					x	1000	Under construction
Cleveland, Ohio								x	x	x						1800-2000	Planning
Cuyahoga Valley, Ohio				x				x	x	x						2000	Engineering
State of Delaware	x	x	x		x			x	x	x						750	Planning
East Bridgewater, Mass.	x	x	x	x				x	x	x					x	500	Startup operations
Franklin, Ohio			x					x	x	x						50	Operational
Knoxville, Tenn.-TVA								x	x	x						3000	Planning
Milwaukee, Wisc.								x	x	x					x	1200-1500	Planning
Nashville, Tenn.	x	x	x					x	x	x						720	Operational
New Orleans, La.		x	x		x			x	x	x						650	Under construction
Pompano Beach, Fla.	x	x	x					x	x	x						50-100	Engineering
Rochester, N.Y.		x	x		x			x	x	x						2000	Planning-Engineering
St. Louis, Mo	x	x	x					x	x	x						8000	Planning & Operational
San Diego, Calif.	x	x	x					x	x	x						--	Construction
Saugus, Mass.		x	x					x	x	x						1200	Operational
Scranton, Pa.	x	x	x					x	x	x						600	Planning
South Charleston, W. Va.	x							x	x	x						200	Demonstration plant

waste disposal and air pollution technology, be capable of conducting pilot-scale R&D at (possibly) remote locations, and be versed in cost engineering and environmental analyses.

- Development of a "Guide for Local Government Decision Makers for Interpreting Cost Data of Solid Waste Energy Recovery Systems that Produce Processed Waste for Use as a Supplemental Fuel in Existing Coal-Fired, Steam-Electric Boilers." (EPA RFP WA-76-B135, CBD 5/20/76)
- Pilot Scale Investigations to Utilize Organic Residues to Produce Usable Fuels and to Improve Sludge Dewatering Characteristics; Determination of the Effects of Gas and Mechanical Mixing (EPA RFP CI-76-0234, Negotiations will be conducted with: System Technology Corp., 245 N. Valley Rd., Xenia, Ohio, CBD 5/11/76)
- Utilization of Wastes as Fossil Fuel Energy Substitutes, (EPA RFP CI 76-0223, CBD 5/3/76, Modification to Contract No. 68-02-2101. Negotiations will be conducted with the Ralph M. Parsons Co., 100 West Walnut St. Pasadena, Calif. 91124)
- Conducting of a Four-phase Program to Assess and Analyze Current European State-of-the-art and Status of R&D and Demonstration in the Conversion of Waste Material to Energy Sources (EPA ERDA RFP-2103)
- St. Louis Union Electric Refuse Energy Demonstration. Additional effort under Contract No. 68-02-1871 to Midwest Research Institute (EPA RFP DU-76-4131, CBD 3/11/76), for the determination of hazardous emissions.

SECTION X

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